August 2001

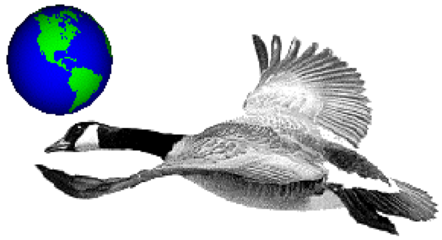
Enhancements to the United States Bird Avoidance Model (US BAM)

Timothy Beermann
Geo InSight International, Inc.

Matthew Bobo
Geo InSight International, Inc.

Russell P. DeFusco
BASH Inc.

Enhancements to the United States Bird Avoidance Model (US BAM)



Timothy Beermann
Geo InSight International, Inc.

Matthew Bobo
Geo InSight International, Inc.

Russell P. DeFusco, PhD
Vice President, BASH Inc.

ABSTRACT

The United States Bird Avoidance Model (US BAM) uses Geographic Information System (GIS) technology to analyze and correlate bird habitat, migration, and breeding characteristics with key environmental and human-made geospatial features. The application consists of raster grids covering the conterminous United States. The value for each grid pixel location is equivalent to the sum of the mean bird mass (in ounces) for all species present during one of four daily time periods (dawn, day, dusk, and night), for one of 26 two-week periods in a year.

The US BAM is a desktop application that has an intuitive design and includes separate interfaces for multiple user profiles such as Air Crews, Flight Planners/Schedulers, and Environmental Planners. It was developed using ESRI's ArcView GIS. Geo InSight has created this ArcView GIS functionality and interface in a web-based environment for the U.S. Air Force.

Current and future enhancements to the US BAM include the creation of an environmental planner and civilian FAA interface, automating Digital Aeronautical Flight Information updates, allowing users to enter new routes, enhancing risk surface generation by linking species distributions to various landscape variables (e.g., topography, land use) and migration patterns, and developing the capability to display portions of bird species groups that compose the risk surface.

1.0 INTRODUCTION

Since 1985 there have been over 38,000 bird-aircraft strikes recorded by the United States Air Force (USAF) alone. These strikes have caused 33 fatalities, 19 lost aircraft, and more than $500 million dollars worth of equipment damage. Twenty four percent of all bird strikes occurred on low level training routes or over military operations areas. Two-thirds (65%) of total equipment damage occurred on those same low-level training routes and military operations areas.

Geo InSight International, Incorporated developed the United States Bird Avoidance Model (US BAM) under contract with the United States Air Force. The US BAM is a predictive tool that can be used by the Armed Forces to help protect human lives, equipment, and wildlife during air operations throughout the conterminous United States.

2.0 THE UNITED STATES BIRD AVOIDANCE MODEL

The objective of the US BAM program was to develop a predictive bird avoidance model using Geographic Information System (GIS) technology as a key tool for the analysis and correlation of bird habitat, migration, and breeding characteristics with key environmental, and human-made geospatial data.

The US BAM consists of geospatial (map) information organized as raster grids or cells. The value for each cell (or pixel) of the model is equivalent to the sum of the mean bird mass (in ounces) for all bird species present during one of four daily time periods (dawn, day, dusk, and night), for one of 26 two-week periods in a year.

The bird species dataset was derived from discrete geographic information for observations of 60 key Bird Aircraft Strike Hazard (BASH) bird species over a 30-year period. The species data were acquired from several key datasets, including the Audubon Society's Christmas Bird Count (CBC), the US Biologic Survey's Breeding Bird Survey (BBS), wildlife refuge arrival and departure data for the conterminous US, and many additional data that are specific to particular bird species.

The bird abundance observations were interpolated using an inverse distance weighted method to reduce interpolation bias. The interpolated abundance values were then converted to bird mass using the mean weight of adult birds, measured in ounces. The bird species data were then combined for different species groups based upon common behavior. The species groups were then modeled for four daily time periods (dawn, day, dusk, and night), for each of 26 annual two-week periods.

2.1 US BAM Application

A GIS application was developed that provides an interface to query and access US BAM data. The application was developed from requirements that were gathered from USAF safety, pilot, navigator, airspace planner, scheduler, and environmental planning personnel. The application includes separate interfaces for Air Crew, Flight Planner/Scheduler, and Environmental Planner user profiles.

The US BAM application was developed using commercial-off-the-shelf (COTS) GIS software. The US BAM was developed using and operates on ESRI's ArcView GIS and can be used with other office, network, and technical applications. The application operates on Microsoft Windows personal computers. The US BAM application enables users to view predictive risk surfaces as well as many other geospatial data themes. These themes include but are not limited to: digital elevation model (DEM) and shaded relief of the conterminous United States; state boundaries, county boundaries, military airfields, military heliports, point data from the Bird Aircraft Strike Hazard (BASH) Team and FAA bird strike databases, major cities, major highways, and numerous other themes. The map legend on the application gives the user point-and-click access to these themes and describes the different graphic components on the display.

The risk levels describe three predicted risk classes -- Low, Moderate, and Severe -- that are based upon the bird mass in ounces per kilometer squared. In other words, the risk levels represent the amount of birds (bird mass) in a two-dimensional square kilometer of airspace. Risk is based on a logarithmic scale. The "Moderate Zone" indicates a risk ratio that is 57-708 times the risk of the "Low Zone," whereas the "Severe Zone" indicates a risk ratio that is 2,503-38,647 times the risk of the "Low Zone."

2.2 US BAM Internet Map Server Application

The functionality and interface of the US BAM application is available in a web-based environment at www.ahas.com. The web site provides information, a frequently asked questions list, and instructions for using the models. The site also allows users to create and interact with maps that display the models along with other geospatial themes. The Internet Map Server application was created by Geo InSight using technology from Allaire ColdFusion and ESRI's ArcIMS.

The web site is hosted by Geo-Marine, Inc. and uses Microsoft Internet Information Server (IIS) and Allaire ColdFusion. ColdFusion provides the capability to dynamically generate Arc eXtensible Markup Language (ArcXML) statements to render the maps created by ESRI's ArcIMS. The site also uses DHTML (dynamic hyper-text markup language) and JavaScript.

3.0 PAST DEVELOPMENT PHASES

The original research methodology that was applied during the development of the conterminous US BAM was approached in eight phases of development. These eight phases included:

PHASE I – Data Collection and Processing

PHASE II – CBC and BBS Interpolated Grids - Initial Model Development

PHASE III – CBC and BBS Predictive Risk Grids

PHASE IV – CBC and BBS Species Group Grids

PHASE V - Species Group Time Interval Grids

PHASE VI - Daily Activity By Season Grids

PHASE VII - Simplified Risk Category Time Interval Grids

PHASE VIII – Application and Web Development

4.0 ENHANCEMENTS TO THE US BAM

The next generation of the United States Bird Avoidance Model will include an enhancement of the existing model using GIS technology to integrate additional data sources. Efforts are also being made to improve user profiles in the existing BAM Internet IMS application as well as to add new user interfaces.

4.1 Automate DAFIF Updates

In order to keep the data included in the US BAM as up to date as possible, an automated program is being developed for updating National Image and Mapping Association (NIMA) Digital Aeronautical Flight Information Files (DAFIF). The NIMA DAFIF data used in the US BAM include the location of Instrument Routes (IR), Visual Routes (VR), Slow Routes (SR), Special Use Air Space (SUAS), Restricted Air Space, Military Airfields, and Military Heliports. This information is updated by NIMA every 28 days.

To ensure the timely update of this information in the US BAM, an application will be developed that will automatically read the NIMA DAFIF files that are utilized in the US BAM and replace the old thematic layers with thematic layers created from the updated files. The application will also take the data provided for instrument routes, visual routes, and slow routes, and automatically generate polygons to represent these routes. The polygons used to represent these routes will replace the old method that displayed only centerlines. The polygons will overlay the centerlines and will represent the allowable deviation from the centerline.

To help streamline this process, the current database structure of the US BAM will be modified so that it mimics the current database structure of the NIMA DAFIF data. This process will help to ensure that new NIMA DAFIF data will be implemented into the US BAM as soon as possible.

4.2 Re-evaluate Statistical Analyses

The original interpolated grids were produced to create a large-scale summary of the available data. These grids were developed using an Inverse Distance Weighted (IDW) method to reduce interpolation bias. A more intensive analysis will be conducted to test for more accurate modeling practices and interpolation procedures.

Geostatistical models such as Kriging, CoKriging, and a number of other smoothing procedures will be applied to the data and the results analyzed. The purpose of these analyses is to try and determine if other geostatistical methods will result in a more realistic surface interpretation. Model validation of the estimated risk surfaces will be conducted by reserving some of the BBS and CBC points for testing purposes. A sample of points will be used to determine which interpolation procedure best approximates the existing data.

These expanded analyses will also explore combining other spatial data with the CBC and BBS to even further refine the risk surfaces. This includes combining elevation and land cover data directly into the geostatistical procedures through the use of CoKriging or employing these data to serve as barriers to avian distributions. Ridges, water bodies, and the presence of various other landforms are known to effect the distribution of birds. This information will be embedded into the risk surface generation phases using various small-scale national spatial datasets.

Another reason for reworking the statistically derived risk surfaces is to allow the inclusion of new BBS and CBC data. The current BAM risk surfaces are based off of data from 1966 – 1991. The BBS and CBC databases have since been updated to include data collected up to year 2000. In the time period between the data used for the current risk surfaces and the most recent updates several species of birds included in the BAM have had changes in their abundance and distribution. Including the new BBS and CBC data will enable BAM to reflect these changes.

4.3 Link Migration to Topography

Further enhancements to the risk surface will be obtained by linking the migration of birds to topographic features such as waterways, ridgelines, land use, etc. Topography based movement rules will be defined by an ornithologist for each target species using data collected from the USDA National Wildlife Center, USDA MIS Support Center, the Hawk Migration Association of North America (HMANA), Ducks Unlimited, Geo-Marine Incorporated through their Avian Hazard Avoidance System (AHAS) work, and various other sources. Data associated with land use, land cover, and atmospheric data of the conterminous United States developed from 1 km^2 AVHRR datasets will also be employed. Geospatial statistical analysis will be used to determine when ecological and atmospheric conditions direct the timing and direction of migratory patterns.

The priority species for which topographical movement rules will be applied are listed below in order of importance. The order of importance was decided by the Unites States Air Force Bird/Wildlife Aircraft Strike Hazard (BASH) Team, Dr. Russell DeFusco of BASH Incorporated, and Adam Kelly and Ron Merritt of Geo-Marine Incorporated.

1. Turkey Vultures
2. Red Tailed Hawks
3. Canadian Geese
4. Black Vultures
5. Dabbling Ducks
6. White Pelicans
7. Golden and Bald Eagles
8. Sandhill Cranes
9. Gulls
10. Tundra Swans
11. Black Birds

Because the modeling of bird movement occurs at the species group level, these species noted above were placed into their respective species groups and will be modeled according to the following priority order:

1. Raptors
2. Geese
3. Ducks
4. Pelicans
5. Cranes
6. Gulls
7. Swans
8. Blackbirds

4.4 Risk Surface Species Composition

Currently, the risk surface demonstrates the amount of bird mass that can be expected in any given area at a given time. Efforts are under way to improve the information conveyed by the risk surface. These efforts include identifying the types of birds that are present across the risk surface and the percentage of those bird types that comprise the surface. Associating the species groups with each two-week period and four daily time periods is the basis for this effort. The different bird species that are actually present and that comprise the bird mass per square kilometer of the risk surface will be identified for the four time periods of each two-week period (104 grids total). Dividing the total mass grid by each of the active species group's grids will provide an indication of the proportion each species group contributes to the overall risk surface. The percentage of each species that makes up the risk surface can then be displayed as a chart.

4.5 Differentiation of Bird Strike Locations by Time Period

It is now possible for US BAM users to display and view bird strike data that has been differentiated by the time period that they have selected. While a green bird strike icon indicates the location of a given bird strike, a red icon indicates that a particular bird strike occurred during the time period that is being viewed. This gives the user a visual indication of how many of the recorded bird strikes occurred during the time period for which the user is planning.

4.6 Adjusted Risk Classes

Previously, the risk surface was described by using three predicted risk classes -- Low, Moderate, and Severe -- that indicate the bird mass values. This risk class legend has been updated to include a total of nine predictive risk classes. The classes have been simplified to assist in user interpretation but represent actual bird mass values as represented below (note logarithmic scale):

CLASS	BIRD MASS (ounces per square km)	AVERAGE PREDICTED RISK RATIO
LOW 1	0 - 140	-
LOW 2	141 – 494	4.5 times the risk of LOW 1
LOW 3	495 - 1,748	16 times the risk of LOW 1
MODERATE 1	1,749 - 6,181	57 times the risk of LOW 1
MODERATE 2	6,182 - 21,854	200 times the risk of LOW 1
MODERATE 3	21,855 - 77,269	708 times the risk of LOW 1
SEVERE 1	77,270 - 273,201	2,503 times the risk of LOW 1
SEVERE 2	273,202 - 965,954	8,851 times the risk of LOW 1
SEVERE 3	965,955 - 4,444,555	38,647 times the risk of LOW 1

4.7 Expanded User Group Interfaces

The US BAM web site has three different military interfaces for different user groups. In addition, there is an FAA interface for civilian user groups. The Air Crew's interface offers five basic themes (i.e., relative risk surface, state boundaries, latitude/longitude graticules, cities, and ground elevation).

The Planner's/Scheduler's interface offers an additional 10 themes that are not found in the Air Crew Interface. These additional 10 themes include instrument routes, slow routes, visual routes, special use air space, air refueling routes, as well as the location of airfields, heliports, recorded bird-strikes, interstates, and land fills.

The newest interface has been designed and implemented for Environmental Planners. Its purpose is to assist Environmental Planners with environmental impact statements, environmental analyses, and NEPA compliance. The Environmental Planners interface includes all of the themes from the two other interfaces, plus 12 additional themes. These additional themes are: dams, CBC sites, BBS sites, golf courses, refuge sites, Next Generation Weather Radar (NEXRAD) sites, NEXRAD radar sites that are capable of bird detection (e.g., Avian Hazard Advisory System [AHAS]), rivers, national parks, other parks, water features (lakes, etc.), and land cover.

Alongside the interface for military pilots and planners is a new interface designed for civilian pilots and planners. This civilian interface incorporates data from the Federal Aviation Administration (FAA), and includes their bird strike statistics and civilian airport locations. This new functionality attached to the US BAM web site is hosted by the United States Air Force.

The FAA site allows civilian pilots to access the model by selecting either the region in which they are interested (regions are divided into Central, Eastern, Midwest, Mountain, Northern, Southern, and Western), or by the state in which the airport resides. This interface allows access to the same model viewed by Air Force users and utilizes the same time periods. The thematic data layers include the relative risk surface, state boundaries, latitude/longitude graticules, the locations of airports, the location of bird strikes recorded by the U.S. Air Force, the locations of bird strikes recorded by the FAA, interstate highways, cities, CBC sites, BBS sites, refuge sites, and an elevation surface.

4.8 Custom Route Depiction

The web application has been modified so that users can now add their own customized routes by selecting the "route tool" from the map view. This tool allows the user to enter the latitude/longitude coordinate nodes that make up the user-determined route.

Upon selecting the "Plot Route" button from the main map page, a dialogue box appears, prompting the user the enter the latitude and longitude coordinates for their own route. The user is also given the ability to enter a label for each leg of the route.

The default format for coordinate input is decimal degrees (such that 45 degrees 30 minutes 30 seconds of Latitude is equal to 45.508333). However, it is possible for users to input coordinate data in the decimal minutes format to which they are accustomed (such that 45 degrees 30 minutes 30 seconds of latitude is equal to 45 degrees 30.5 minutes [45-30.5]). By clicking on the small globe icon listed next to each coordinate pair, a dialogue box is opened that takes them through the steps in which they can enter coordinate data in the typical format used by pilots. These coordinates are transformed into decimal degrees.

Users are also able to change the characteristics of the features that they have input (the lines that connect the input coordinates and that define the route). The optional changes include the line color, line style, line width, labels color, whether or not the labels are rotated to run parallel to the route lines, and whether or not the feature is visible. The application is designed so that the user can enter and save a number of different routes. Submitting changes to the added routes automatically refreshes the main map on which the plotted route is graphically displayed.

The user is also provided the option to edit the coordinates and labels that have already been entered, as well as the ability to delete old or add new coordinates. A Zoom to Feature option allows the user to zoom to their entered data on the map.

4.9 Print Format Options

A "Print Friendly" button has been added to the US BAM web application. This button gives users the option of placing their view of interest into a format that is more suited for printing than the format of the web application view.

4.10 Long Range Goals

Radar ornithologists from Geo-Marine Incorporated will assist in the integration of NEXRAD (Next Generation Weather Radar) data on migrating birds and roosting locations into the operational bird avoidance model. They are developing image data sets that separately depict bird species locations and weather data. The bird species location data will be further differentiated using known bird species radar signatures.

Radar-generated image data will then be assimilated into the Bird Avoidance Model in a feedback mechanism with the AHAS. These datasets will be statistically evaluated, using GIS, to determine their applicability and effectiveness as a model variable in comparison with other model data sets.

The radar methodology, GIS data integration, and IMS web interfaces will be reviewed by scientists and engineers through a peer review process. Experts in ornithology and spatial statistics will provide input on improvements and recommend additional data integration.

The end result will be a fusion of near real-time bird movement data and modeled bird behavior from the US BAM surface models. Pilots and planners will be able to access the latest radar derived bird information when planning within a 24-hour period. Any planning for outside of this time frame will reference the historically based Bird Avoidance Model.

5.0 SUMMARY

The US BAM is a predictive tool that can be used by the Armed Forces to help protect human lives, equipment, and wildlife during air operations throughout the conterminous United States. The model consists of a grid surface representing bird mass in ounces per kilometer squared. The amount of bird mass per kilometer squared is used to create the risk surface (the potential risk of striking a bird based on their abundance in a particular area at a particular time). Geo InSight further enhanced the utility of the original US BAM application by making it accessible via the Internet, providing multiple interfaces for multiple users.

Enhancements to the current functionality of the US BAM are intended to improve the accuracy of the risk surface by updating the BBS and CBC data and revising the statistical analyses used to create the surface. Linking bird movement to earth surface topography and integrating the results into the model will also result in an improved risk surface. Automated updates to DAFIF data will help to ensure that the most up-to-date information is available. The functionality of the US BAM will also be improved through the creation of additional user interfaces, such as Environmental Planners and Civilian Pilots. Users of the US BAM will also be able to enter their own routes into the US BAM, and will be able to more efficiently print out the results.

All of the steps listed above will improve the functionality of the US BAM. There is, however, a significant amount of work that still needs to be done. To maximize the usefulness of the US BAM, it must be integrated with near real time data on bird movement made available through AHAS. The melding of the US BAM and AHAS will provide the best available information to pilots and planners who must take bird strike mitigation into account.